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Incremental Capacity Analysis of a Lithium-ion Battery Pack for Different Charging Rates

Theodoros Kalogiannis ^a, Daniel-Ioan Stroe ^a, Jonas Nyborg ^b, Kjeld Nørregaard ^b
Andreas Elkjær Christensen ^c and Erik Schaltz ^a

^a Department of Energy Technology, Aalborg University, Denmark

^b Danish Technological Institute, Aarhus 8000, Denmark

^c Lithium Balance A/S, Hassellunden 13, Smørum, 2765 Denmark

* Email: thk@et.aau.dk

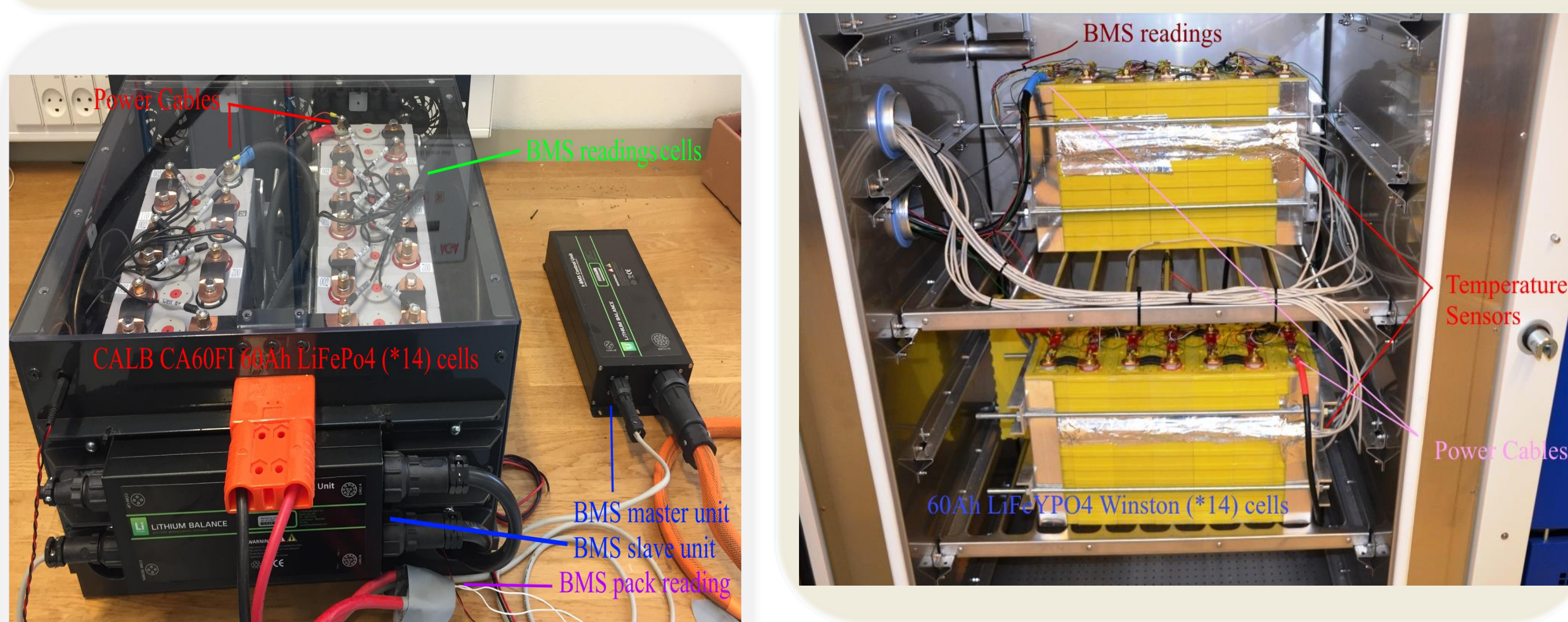


Motivation

Incremental Capacity Analysis (ICA) is a method used to investigate the capacity State-of-Health (SoH) of battery cells [1]. The aim of this poster is to present the challenges for implementing the ICA technique for battery packs, here consisted of 14 cells, by means of different C-rates (C/10, C/6 and C/5) and for several temperatures. LFP chemistry based cells are connected in series to build the packs, for either 60Ah and 160Ah.

Experimental Setup

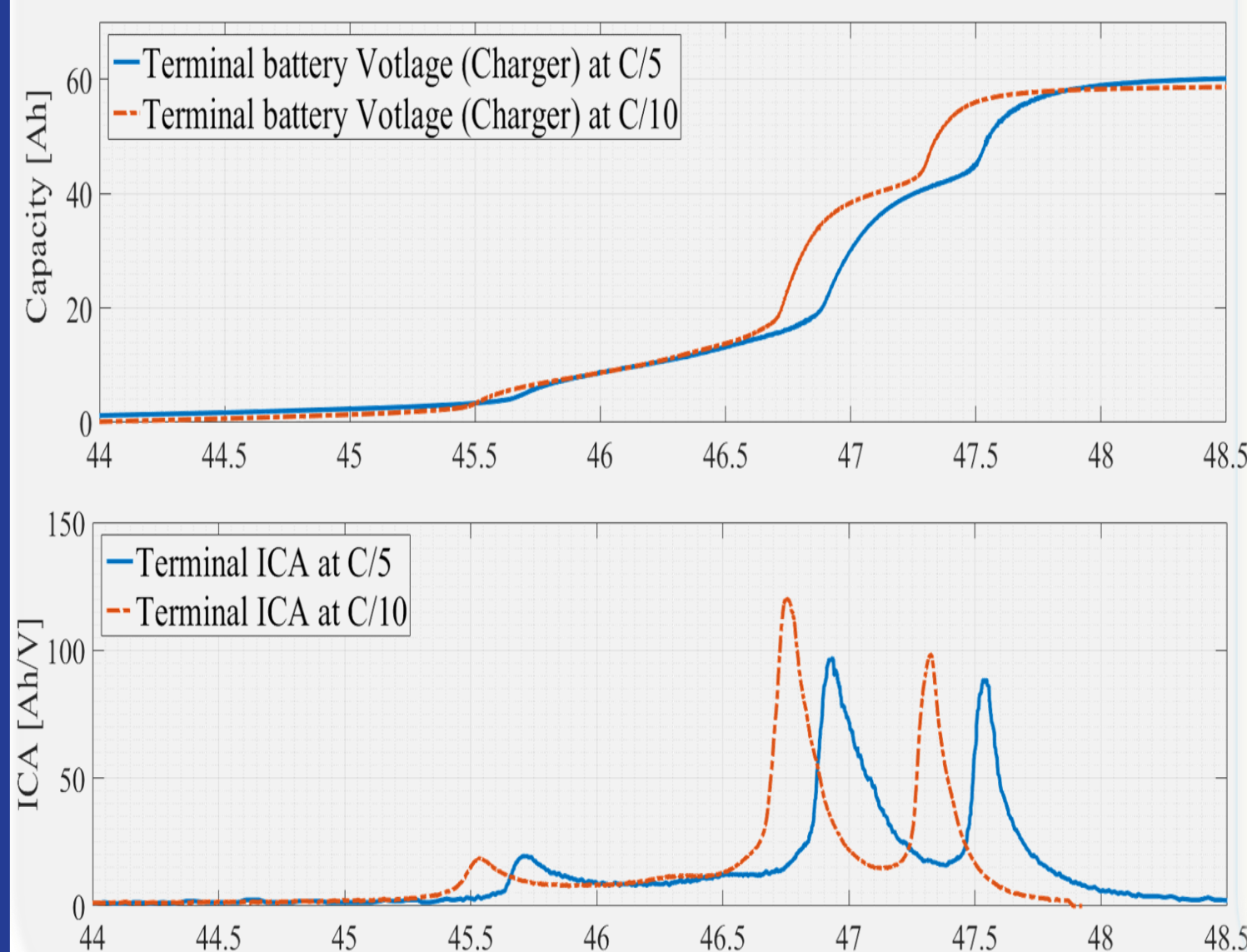
14*Winston 160Ah LiFeYPO₄ cells at C/6 between 5° and 30°C



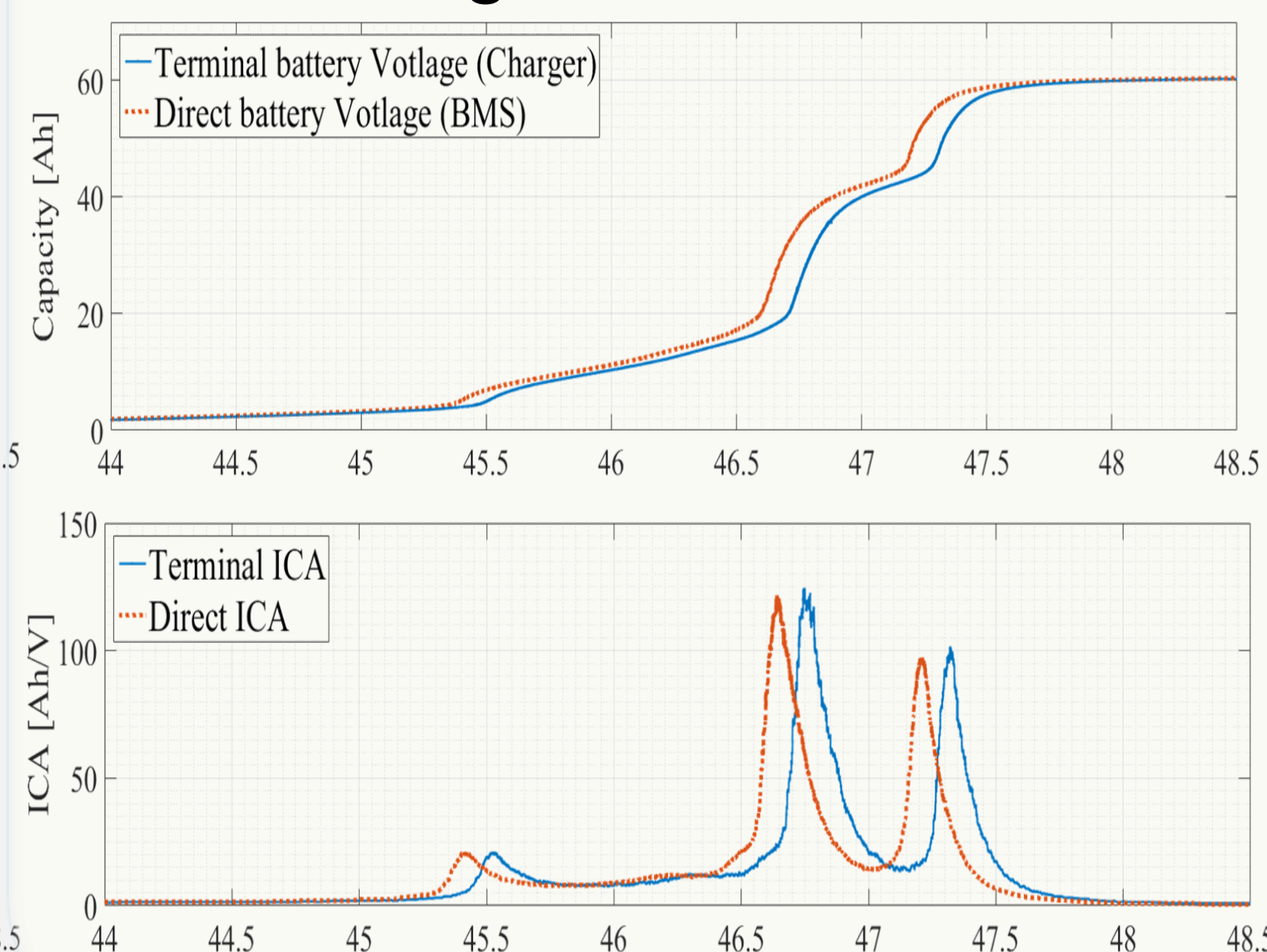
14*CALB 60Ah LiFePo₄ cells at C/5 and C/10 charge current rate

Direct & Terminal ICA

■ **Charge Voltages:** at C/10 & C/5



■ **Charge Voltages:** at C/10 for Charger & BMS



ICA Method

■ **Incremental Capacity Analysis:**

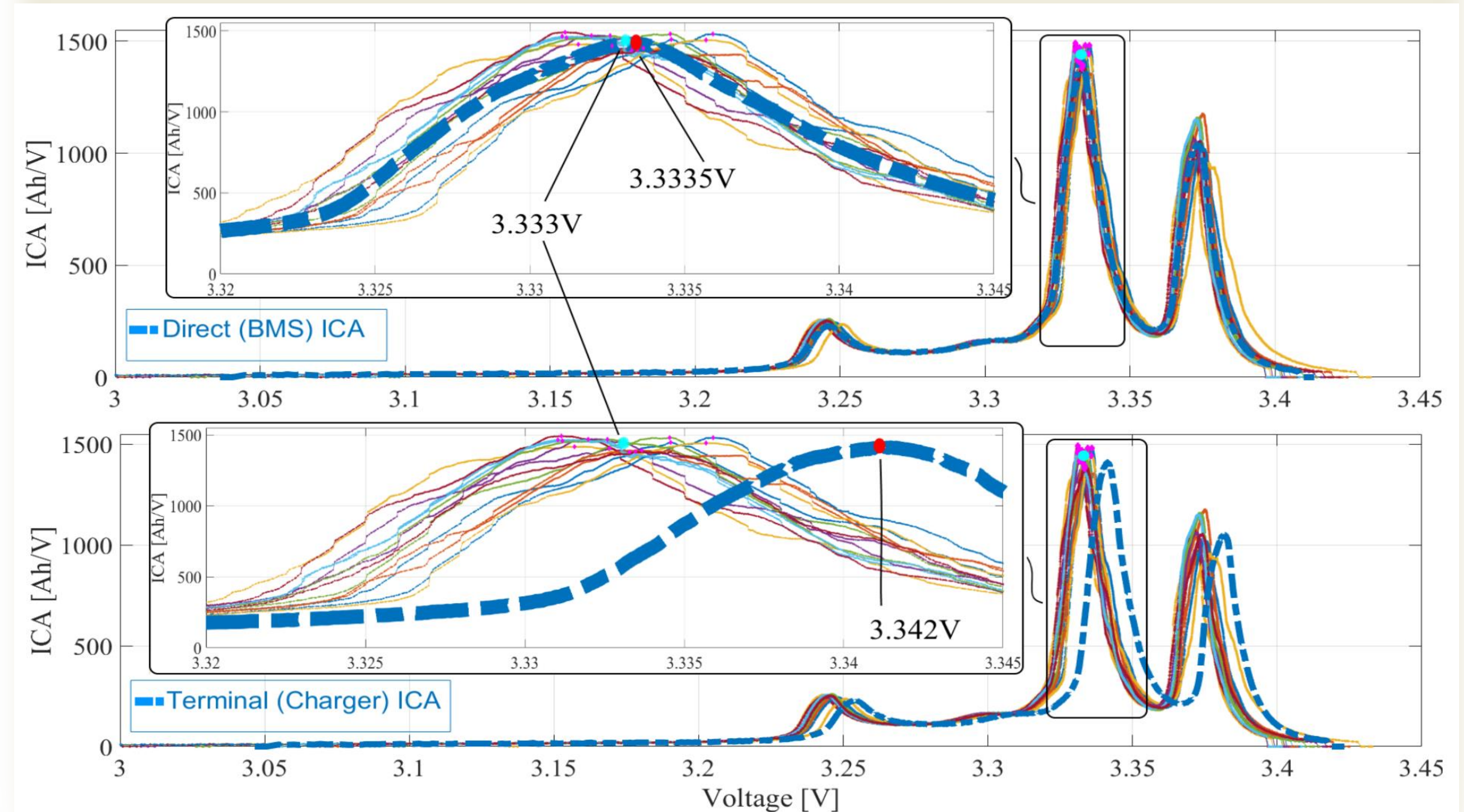
$$IC = \frac{dQ}{dV}$$

■ At a chosen ΔV (5~25mV) [2]

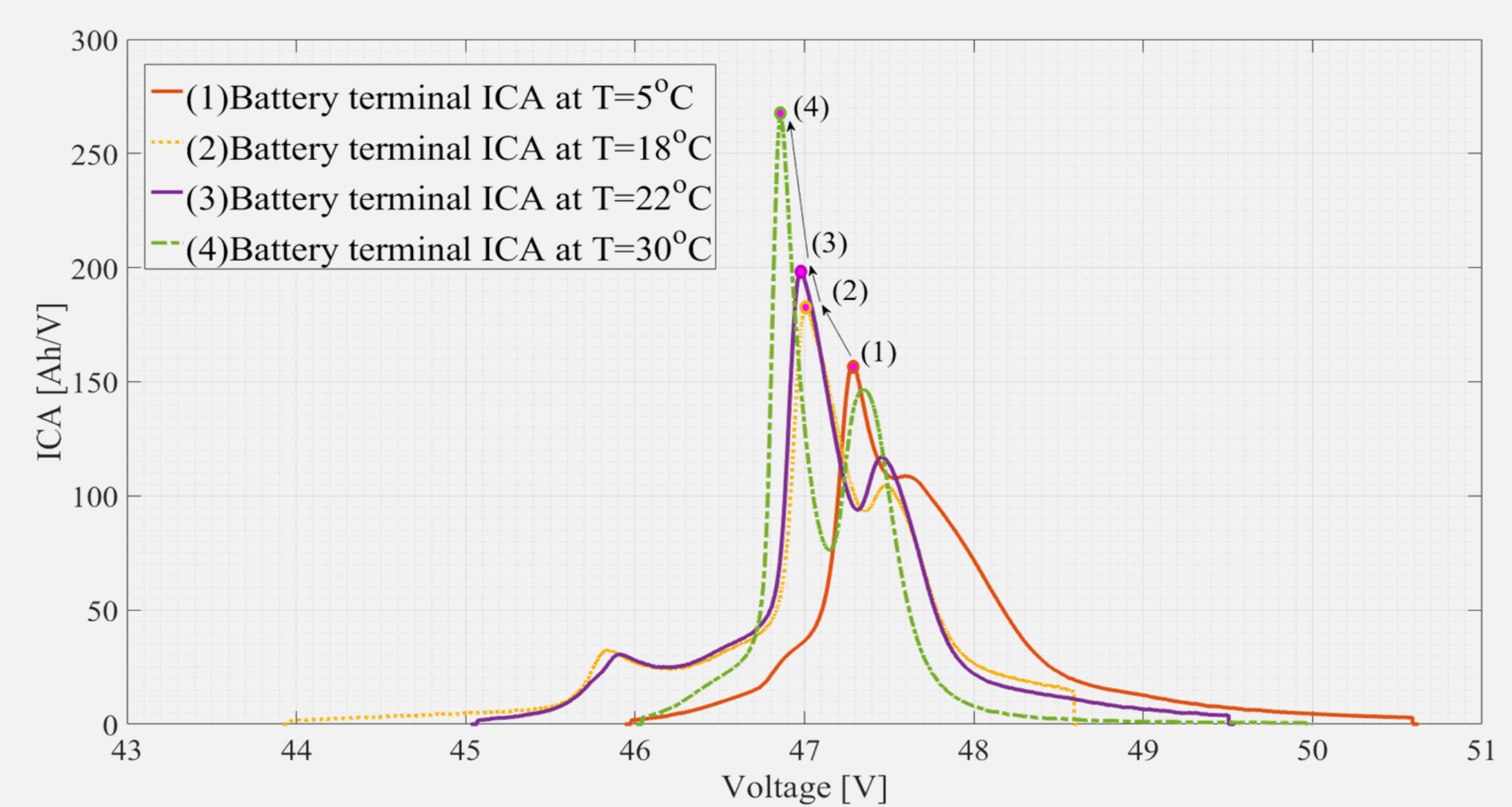
- Several approaches in literature for wide range of chemistries, capacities and cell designs [3]
- For many different C-rates and temperatures [4]
- Significance at a battery pack level not yet established
- Smoothing of raw data and filtering of charge/discharge capacity curves, to achieve an identifiable and unique IC peak

Results

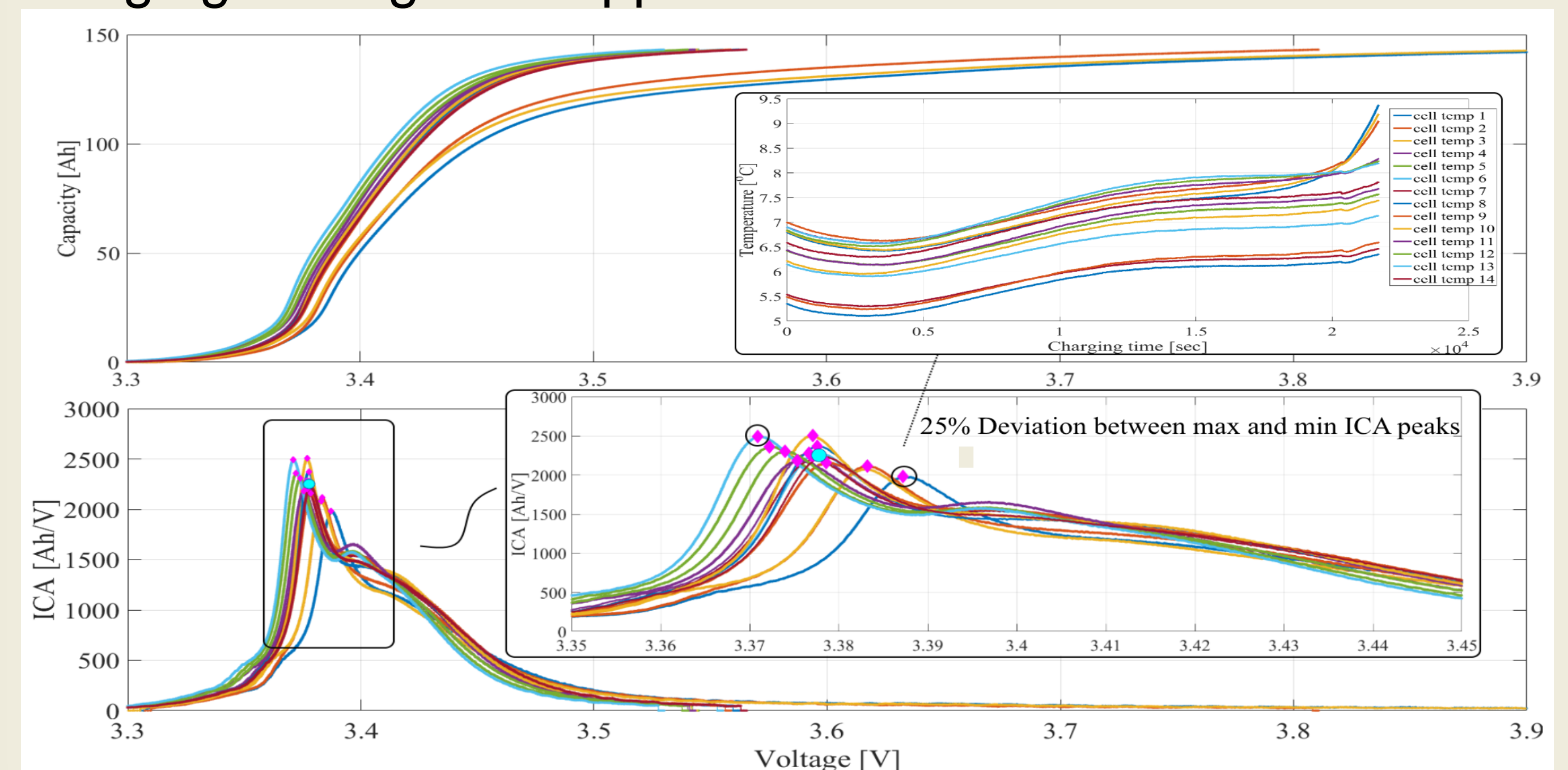
- **Direct ICA:** Less than 1mV deviation to the averaged cells ICA
➢ Accurate cell capacity SoH estimation based on pack readings
- **Terminal ICA:** Approx. 10mV deviation to the averaged ICA



- Terminal ICA sees a higher impedance path compared to direct
- **Variable temperatures for C/6:** For the 160Ah battery pack. The peak moves to the lower voltage levels due to lower resistance, which is caused by a higher temperature



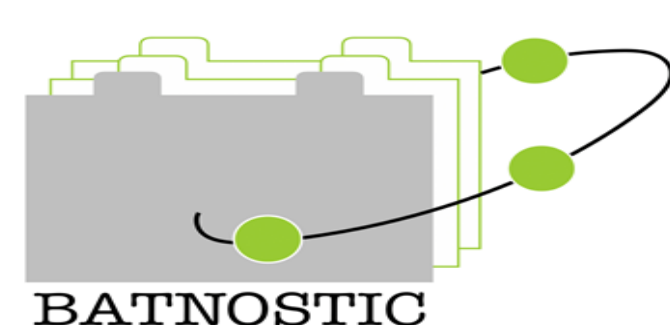
- ICAs influenced from temperature variations on the pack level
- **160Ah battery pack charged with C/6 at 5°C:** spread of the individual cells' peaks due to inactivity of balancing during charging. Charge is stopped when a cell reaches cut-off limit.



- ICAs are influenced from the cell to cell temperature variation

Acknowledgement

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References

- [1] M. Dubarry et al., Electrochem. Solid-State Lett., **9**, A454–A457 (2006).
- [2] X. Han et al., J. Power Sources, **251**, 38–54 (2014).
- [3] M. Safari and C. Delacourt, J. Electrochem. Soc., **158**, A1123–A1135 (2011)
- [4] C. Weng et al., J. Power Sources, **235**, 36–44 (2013)

Conclusion & Future Work

- The additional Z path, the temperature variations and the C-rates must be considered for ICA on a battery pack.
- Terminal ICA is not deriving the actual capacity SoH of the cells.
- Outlook: Lifetime experiments at pack level under certain conditions.